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Equalizing the Electric Field Intensity within Chick Brain Immersed in Buffer Solution at Different Carrier Frequencies

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16. ABSTRACT

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Brief Communication

Equalizing the Electric Field Intensity Within Chick Brain Immersed in Buffer Solution at Different Carrier Frequencies

William T. Joines and Carl F. Blackman

U.S. Environmental Protection Agency, Health Effects Research Laboratory, Experimental Biology Division, Environmental Research Center, Research Triangle Park, North Carolina

Presented here are the numerical relationships between incident power densities that produce the same average electric field intensity within a chick brain half immersed in buffered saline solution and exposed to a uniform electromagnetic field at carrier frequencies of 50, 147, and 450 MHz. Calculations are based on modeling the buffer solution as a spherical shell in air with an inner concentric sphere of brain tissue. The results support our earlier conclusion that calcium efflux results obtained at different carrier frequencies are in agreement when related by the electric field within the brain.

Key words: calcium efflux, complex permittivity, amplitude windows, concentric spheres

In estimating the average electric field intensity within a chick brain half immersed in buffer solution and exposed to a uniform electromagnetic field, our first approximation was to ignore the shielding effect of the buffer solution [Blackman et at, 1980; Joines and Blackman, 1980]. We assumed a spherical sample of brain tissue with a radius (0.71 cm) equal to that of the test tube holding the sample. As a next step in estimating the electric field intensity within the brain, we have made calculations using layered-sphere models [Weber, 1965] that account for the shielding effect of the saline buffer solution surrounding the 0.3 ml chick brain half and that respond to Athey's communication [Athey, 1981]. We outline here some of the results of our calculations on a layered-sphere model; details of the calculation leading to these results will be included in a forthcoming publication.

In these calculations we take the relative complex permittivity of brain tissue (ϵ_r^*) to be 100-j175 at 50 MHz, 66-j69.2 at 147 MHz, and 49-j30 at 450 MHz [Foster et al, 1979], and for the buffer solution we take the relative complex permittivity (ϵ_{sr}^*) to be 71-j580 at 50 MHz, 71-j200 at 147 MHz, and 70.9-j67 at 450 MHz [Schwan, 1957]. These room-temperature values of permittivity were confirmed by measure-

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Address reprint requests to William T. Joines, US Environmental Protection Agency, Health Effects Research Laboratory, Experimental Biology Division (MD-74C), Environmental Research Center, Research Triangle Park, NC 27711.

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ments made at the US Environmental Protection Agency (EPA) based on the methods of Hollis et al [1980]. From these values it is seen that the complex permittivity of buffer solution is greater than that of chick brain, and its frequency dependence is somewhat different from that of chick brain. The effect of the buffer solution is to lower the internal electric field intensity in the brain tissue and to increase the difference between the incident power densities that must be applied at 50, 147, and 450 MHz to produce the same internal electric field intensity.

Using the layered-sphere model, the internal electric field intensity is the same at two different carrier frequencies, denoted by subscripts α and β, if the incident powers are related by the following equation [Joines and Blackman, 1980]:

$$P_{i\beta} = \frac{\left[\left|\frac{3}{M}\right|^2 + 0.1\left(\frac{2\pi a}{\lambda}\right)^2\right]_\alpha}{\left[\left|\frac{3}{M}\right|^2 + 0.1\left(\frac{2\pi a}{\lambda}\right)^2\right]_\beta} \cdot P_{i\alpha} \tag{1}$$

where

$$M = \frac{2}{3}(\epsilon_w^* - \epsilon_r^*)\left(1 - \frac{a^3}{b^3}\right) + 2 + \epsilon_r^*,$$

a is the brain radius (0.415 cm for 0.3 ml), b is the outer radius including the buffer, and λ is wavelength.

If all of the buffer solution (1 ml) is in a spherical layer around the 0.3-ml chick brain, it is possible to show from Equation 1 that the average electric field intensity within the brain is the same at different carrier frequencies when the incident power densities are related by

$$P_{i50} = 6.60\ P_{i147} \tag{2}$$

and

$$P_{i147} = 3.99\ P_{i450} \tag{3}$$

At the other extreme, if no buffer solution (only air) surrounds the 0.3 ml-chick brain, the internal field intensity is the same if the incident power densities are related by

$$P_{i50} = 4.40\ P_{i147} \tag{4}$$

and

$$P_{i147} = 2.80\ P_{i450} \tag{5}$$

The correct relationships are most likely between these two extremes. Since the chick brain is within the tip of the test tube, only about 0.62 ml of buffer solution actually surrounds the chick brain. The remaining 0.38 ml is within a cylindrical layer

above the brain. If the 0.62 ml of buffer solution is in a spherical layer around the 0.3-ml brain, the incident power densities are related by

$$P_{150} = 6.41\ P_{1147} \tag{6}$$

and

$$P_{1147} = 3.84\ P_{1450} \tag{7}$$

Based upon the layered-sphere model, Equations 6 and 7 probably represent the best estimate of the experimental situation. It is noteworthy that even the extreme approximations, Equations 2 - 5 also support our original conclusions that calcium efflux results obtained at different carrier frequencies are in agreement when related by the electric field intensity within the brain tissue [Joines and Blackman, 1980].

The calcium efflux results obtained from each carrier frequency show alternate ranges of efflux enhancement (positive result) and no enhancement (negative result) when displayed versus incident power density. Hence, one would expect the power density ratios P_{150}/P_{1147} and P_{1147}/P_{1450} to alternate between ranges of values that bring similar results into alignment at adjacent carrier frequencies and values that bring the data into conflict by lining up dissimilar results. This is in fact the case, since a P_{150}/P_{1147} value of 5.86 would line up a negative result at 50 MHz (2.17 mW/cm^2) with a positive result at 147 MHz (0.37 mW/cm^2). At present we do not have enough data to show alternate ranges for P_{1147}/P_{1450}.

It should be clear from Equation 1 that the incident power relationship is rather insensitive to small changes in permittivity, since they tend to cancel in the ratio. Hence, choosing permittivity values for the saline buffer solution [Stogryn, 1981] that are somewhat different from the values we have used would have very little effect on the results in Equation 2-7. Likewise, permittivity variation with temperature would tend to cancel in the ratio of Equation 1.

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